Road Tunnel Safety After the Mont Blanc Fire

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Outline

- Introduction
- Mont Blanc Tunnel Fire
- Refurbishment and Modernisation
- Impact on Tunnel Safety
- Outstanding Issues
- Case Study – New Tyne Crossing
- Conclusions

Acknowledgment

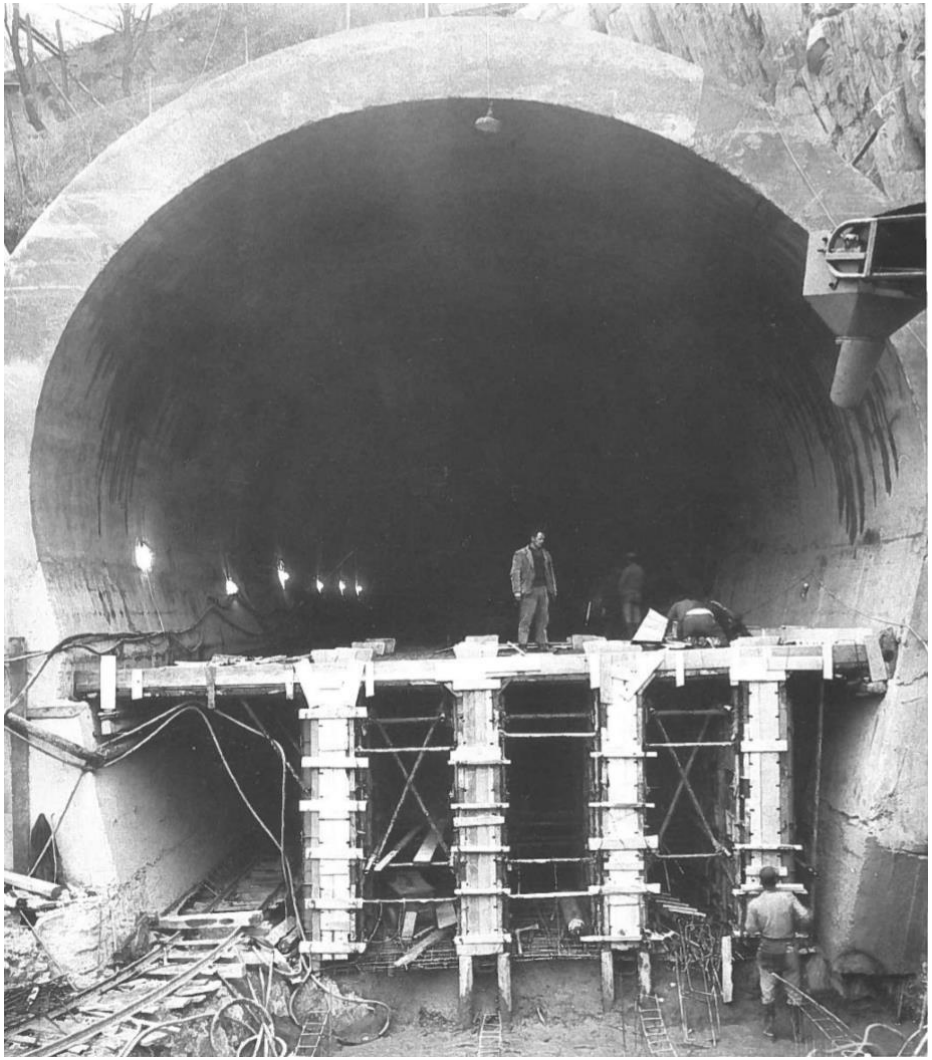
- Thanks to my former colleague Dr Marco Bettelini for preparing the slides relating to the Mont Blanc Tunnel

Introduction

- The fire in the Mont Blanc Tunnel was a turning point in tunnel safety
- The fire occurred on 24 March 1999 and caused 39 fatalities
- Further large fires followed in the Tauern Tunnel in Austria and in the Gotthard tunnel in Switzerland
- These fires permanently changed our approach to tunnel safety

The Mont Blanc Tunnel

- Alpine tunnel between France and Italy
- Commissioned in 1965
- Bidirectional traffic
- Length 11.6 km
- 2 x 3.5 m traffic lanes
- Cross section 46 m^2
- Moderate traffic volumes



Mont Blanc Tunnel Fire

- HGV with margarine
- Mechanical failure?
- 36 vehicles destroyed
- 39 fatalities
- Fire burned for 53 hours and reached temperatures of 1,000 °C
- 900 m structural damage
- Poor French / Italian co-ordination

Mont Blanc Tunnel Fire – Key Events - 1

- Belgian transport truck carrying flour and margarine entered the French-side portal and caught fire in the tunnel.
- After several kilometres, the driver realized something was wrong and unsuccessfully tried to fight the fire.
- Most drivers rolled up their windows and waited for rescue. Many did not survive.

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Mont Blanc Tunnel Fire – Key Events - 2

- Due to meteorological conditions, airflow through the tunnel was from Italy to France.
- Authorities compounded the effect by pumping in further fresh air from the Italian side, feeding the fire and forcing black smoke through the length of the tunnel.
- Fire tenders stalled due to smoke flooding their engines. Fire fighters sheltered in fire cubicles; commander died in hospital.

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Mont Blanc Tunnel Fire - Aftermath

- 3 years of closure
- Large national and regional economic losses
- Tunnel completely refurbished

Investigation and Refurbishment

- National and international investigations
- Design team was selected during summer 1999
- Very high political, economic and public pressure
- Challenging requirements to the design team
- Key requirement: Holistic, performance-based approach for tunnel safety
- Key issues for refurbishment:
  - Tunnel management
  - Tunnel control system
  - Direction of motorists
  - Self-rescue
  - Smoke ventilation
  - Intervention

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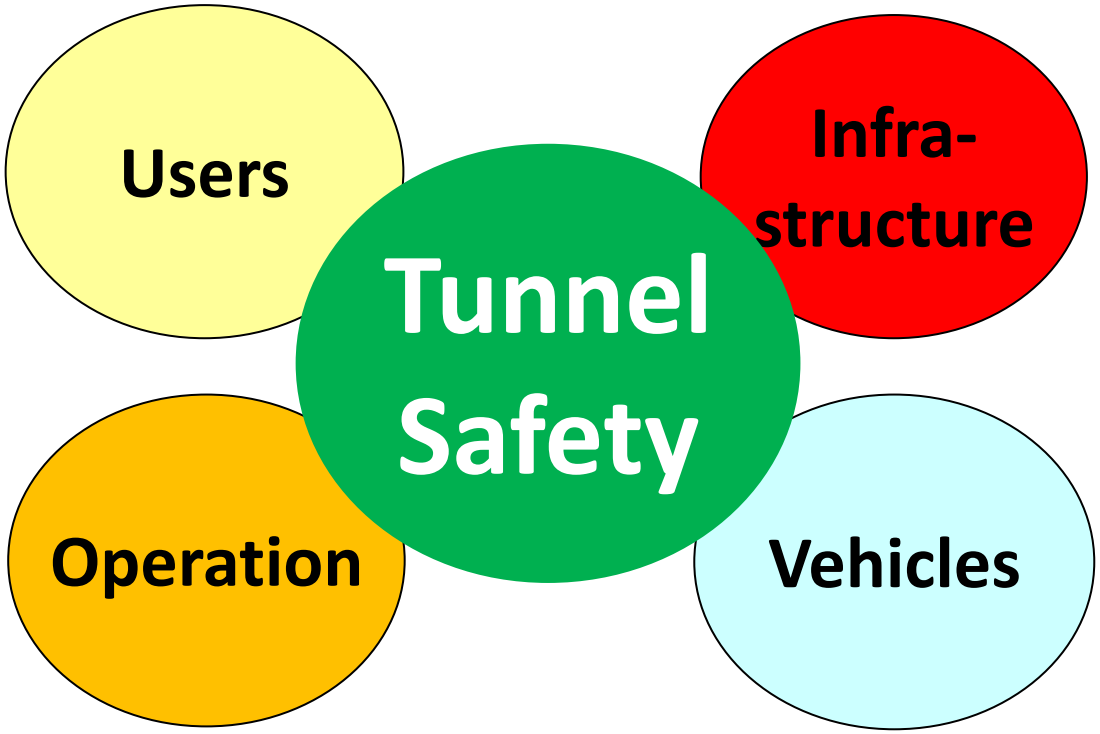
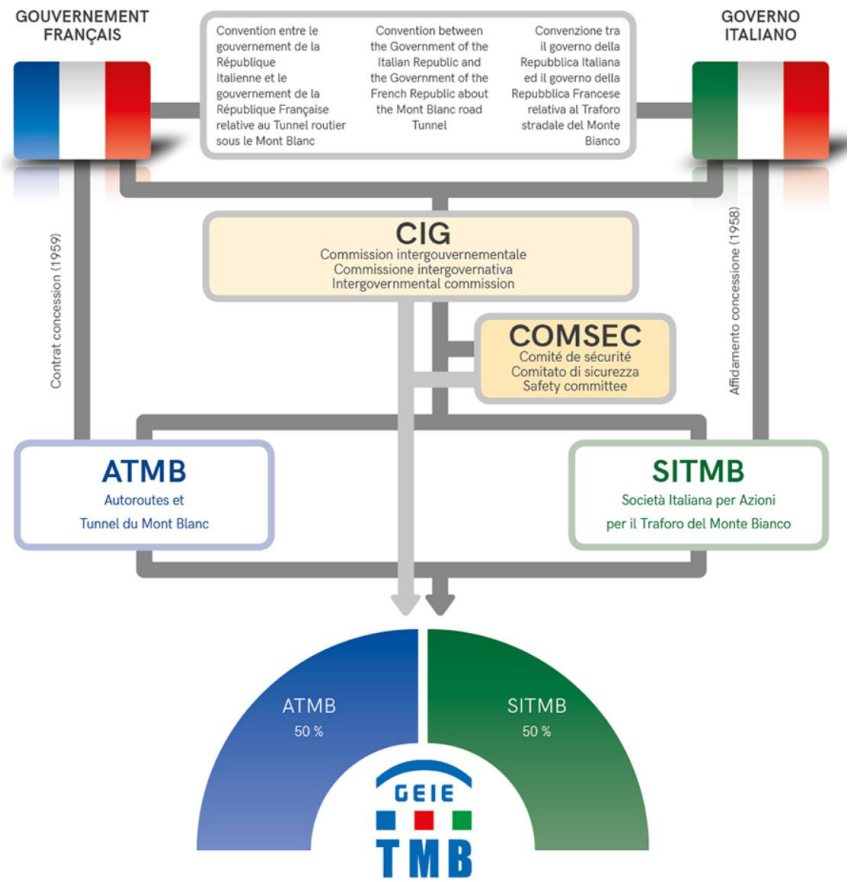
Holistic Approach



UNECE 2001

Tunnel Management

- Single tunnel-management organization MBT-EEIG
- Tunnel manager
- Safety officer
- …



Key Safety Features

- Single emergency communication system for Italians and French
- 37 shelters for escape and firefighting
- HGVs monitored for overheating motors at portals
- Fire detectors every 3 m within tunnel
- 150m minimum distance between vehicles, monitored by radar
- Tunnel barriers at the portals
- Break-in radio frequencies for emergency announcements
- VMS for providing guidance in case of emergency

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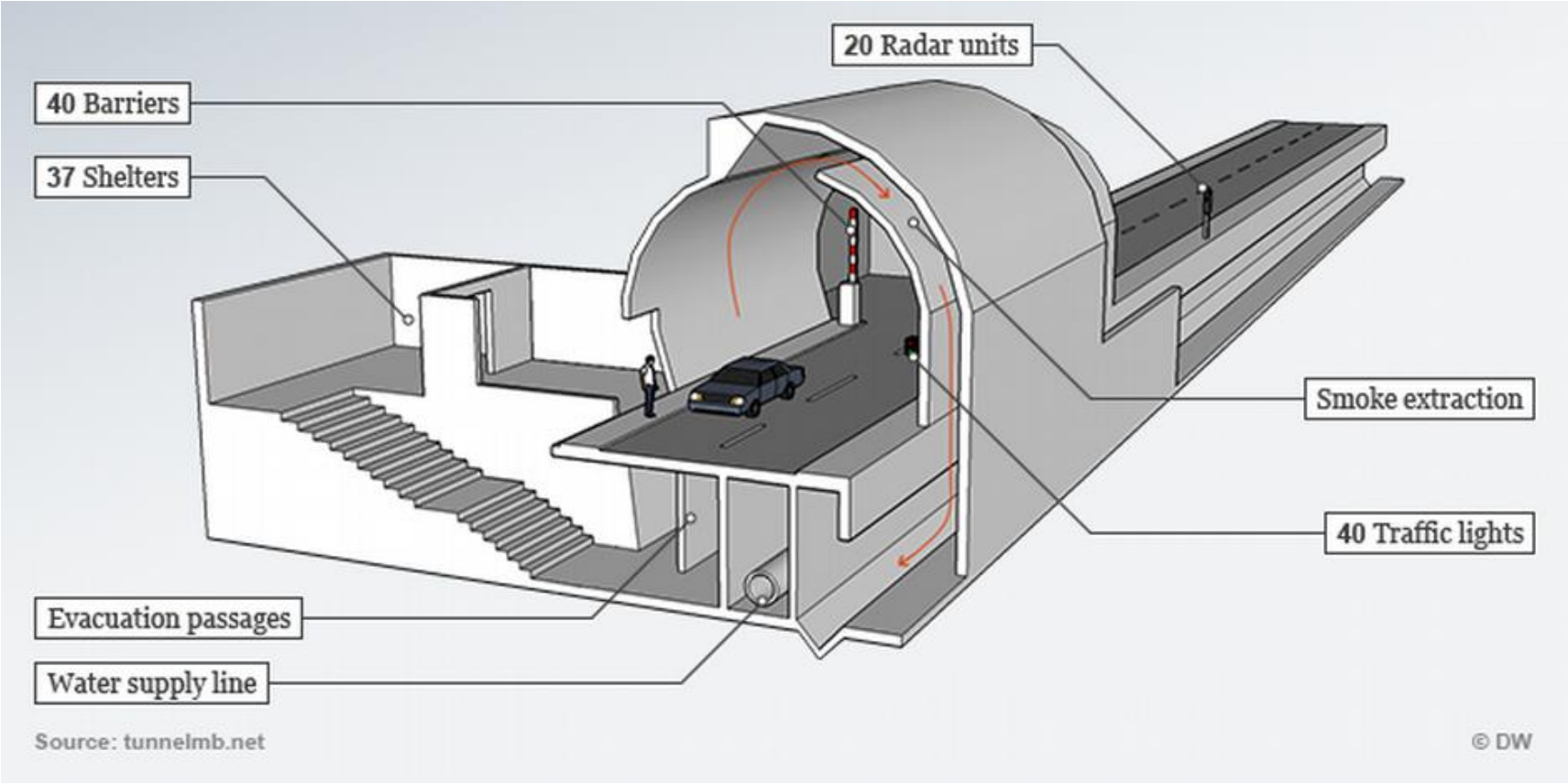
New Safety Arrangements



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Ventilation Design

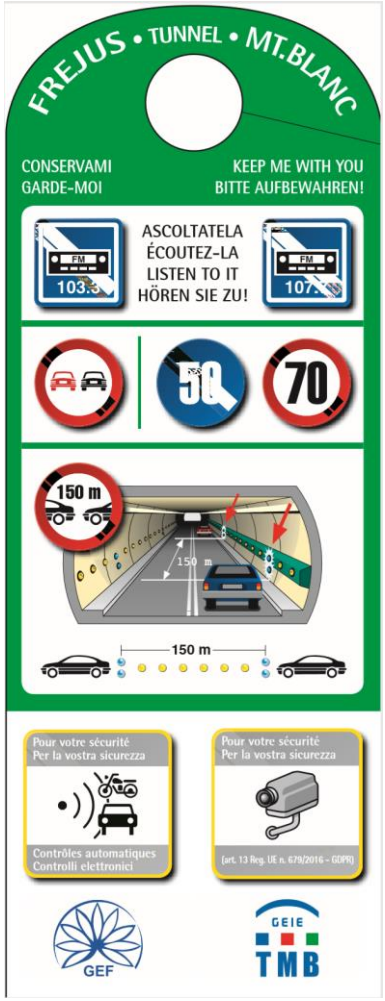
- Distributed fresh air supply
- Smoke extraction every 100 m, min. 150 m^3/s
- Jet fans for longitudinal airflow control

Fire-Fighting

- Professional teams on site + external support
- Portals + centre of the tunnel
- Training and equipment

«Janus»

User Information



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European Response

- Western Europe Road Directors working group composed of representatives of the Alpine countries - common recommendations in September 2000.
- Economic Commission for Europe of the United Nations Organisation - final report in December 2001 on all aspects of road tunnel safety: road users, operation, infrastructure, vehicles.
- European Union funded research projects including DARTS, FIT, UPTUN, SIRTAKI, SAFE TUNNEL and Safe-T.
- European Union enacted a directive on minimum safety requirements for tunnels in the Trans-European Road Network in April 2004.

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UK Implementation

- The UK transposed EU Directive 2004/54/EC into domestic legislation via the Road Tunnel Safety Regulations 2007.
- Emergency walkways, turning galleries, and laybys, not included due to the cost and difficulty of implementation and the risk of additional security hazards.
- Eight road tunnels in scope under the 2007 Regulations: A282 Dartford Tunnel, A1(M) Hatfield Tunnel, M25 Bell Common Tunnel, M25 Holmesdale Tunnel, A299 Ramsgate Tunnel, A55 Conwy Tunnel, A55 Pen-y-Clip Tunnel, and A55 Penmaenbach Tunnel.
- Derogation process for innovative safety equipment or procedures now considered by UK ministers, not EU Commission or the Article 17 Committee.

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Influence on World Road Association (PIARC) Standards

Reports issued in the aftermath of the Mont Blanc Tunnel fire:

- Examples of good practices for the operation and maintenance of road tunnels
- Vehicle emissions and air demand for road tunnels
- Leaflets on ‘safe driving in road tunnels’, produced with the European Commission
- Traffic incident management systems used in road tunnels
- Cross-section design for bi-directional road tunnels
- Quantitative Risk Assessment and Decision Support models jointly developed with the OECD
- Systems and equipment for fire and smoke control in road tunnels

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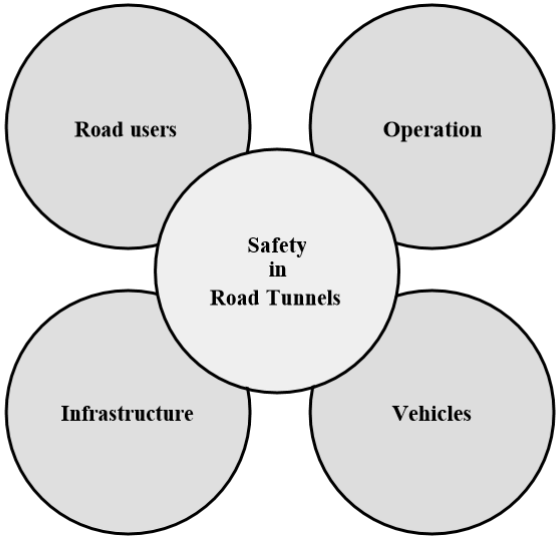
The Evolution of Tunnel Safety

- Approach
  - Holistic vs. System-based
  - Codification
  - Risk analysis

– Codification of Safety
  - UNECE 2001
  - 2004/54/EC
  - National regulations
  - ITA, PIARC, …



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European Directive 2004/54/EC

- Restricted to tunnels on Trans-European Road Network (but serves as a guideline for other tunnels)
- Sets out the safety responsibilities for defined bodies
  - Administrative Authority
  - Tunnel Manager
  - Safety Officer
  - Inspection Entity
- Defines circumstances where risk analysis may be used (e.g. for innovative techniques)
- Requires Member States to report fires and accidents in tunnels
- Includes an annex with minimum safety infrastructure

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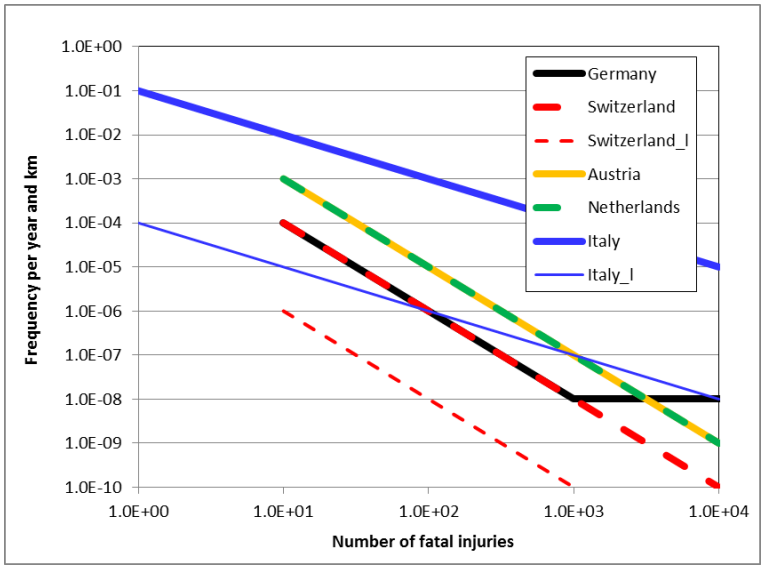
Some Challenges

- Risk assessment approaches
- Innovative techniques
- System complexity
- Initial and operating costs
- Route-wide safety

Prescriptive vs Performance-Based Measures

- Risk acceptability limits vary from country to country
- Wide spectrum of risk analysis approaches used in Europe (e.g. scenario-based, system-based)
- Role of minimum tunnel operating requirements is undefined



Tunnel Refurbishment Process

- Implementation of 2004/54/EC is heterogeneous
- Some countries almost completed: France, Switzerland, Germany, Austria, Netherlands, …
- Other countries are still working on implementation
- Status very heterogeneous:
  - TERN vs. remaining network
  - National vs. local authorities
  - Increasing gap between state-of-the-art tunnel and old network

System Complexity

Shelters

Signs

Emergency exits

Emergency Cabinet

Lighting

Ventilation

Control room

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Innovation

- Innovative approaches expressly permitted by European Directive
- Recent examples: low-pressure mist systems, jet fans with shaped nozzles
- However: conservative operators and regulators; procurement contractually separated from operation
- Evidence on performance and cost benefits must be clear to overcome conservatism

MoJet in Mersey Queensway Tunnel

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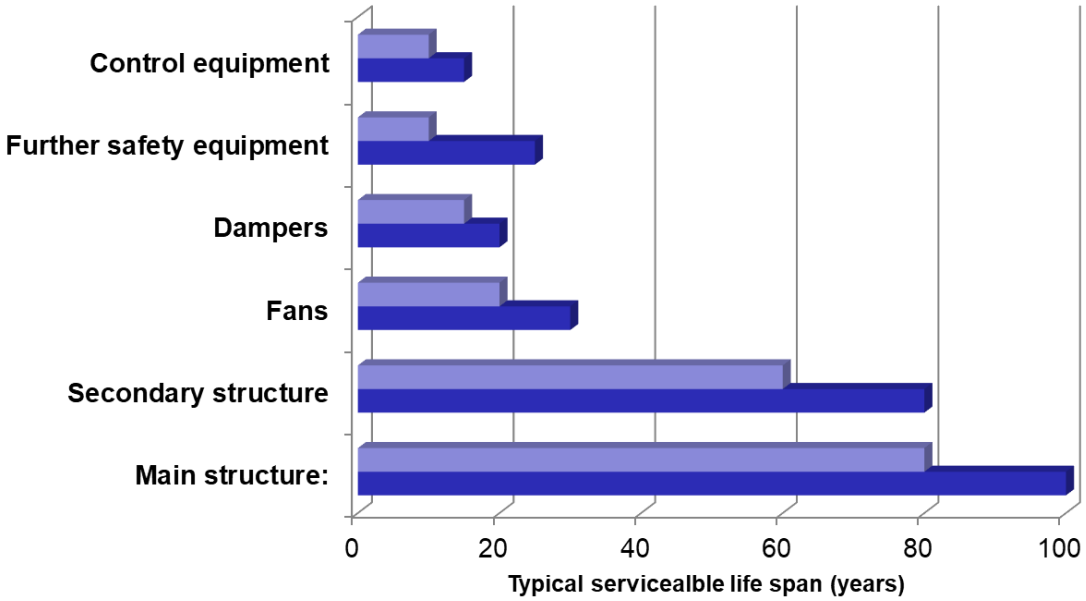
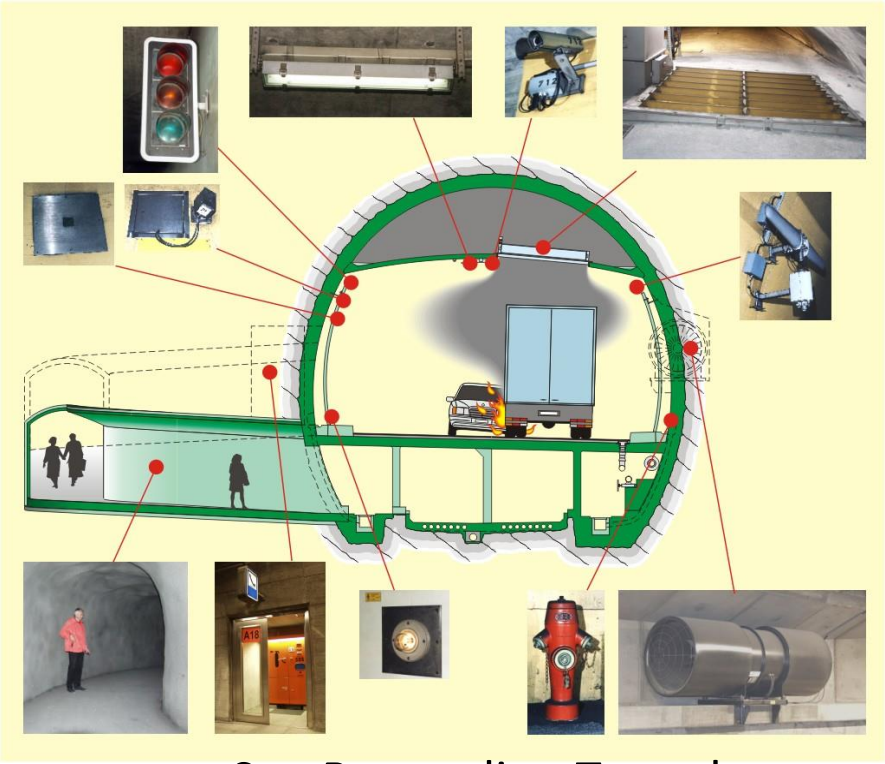
Service Life

- Structural components: 60-100 years
- Safety equipment: 20-30 years
- Control system: 10-15 years
- Retrofitting / refurbishment costs
- Residual life and hand-back requirements



Aging Equipment

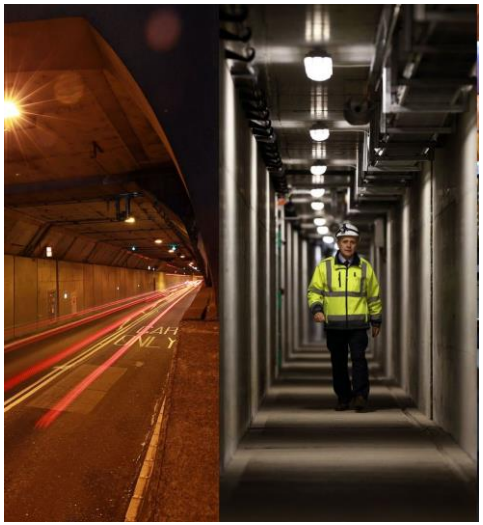
- Emergency exits
- Ventilation system
- Ducts
- Fans
- Dampers
- Sensors
- Safety niches
- Water supply
- ….



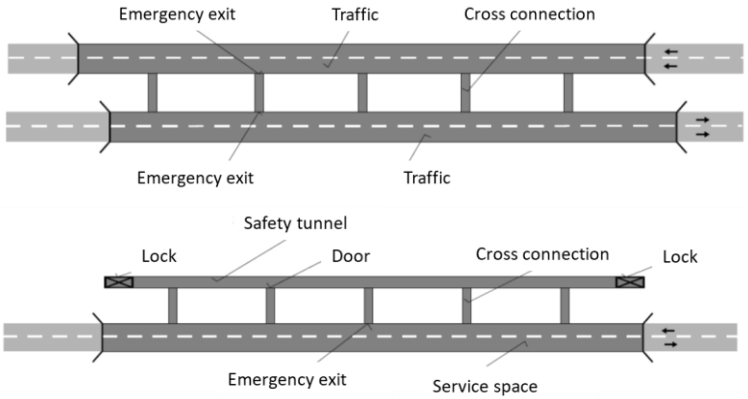
San Bernardino Tunnel

Emergency Exits

- Cross-passages generally required every 100m in UK
- However: construction complexity and cost
- Extended to 150m for new Silvertown Tunnel in London, based on risk assessment (fire-fighter response)
- Safety tunnels constructed in parallel to European existing road tunnels

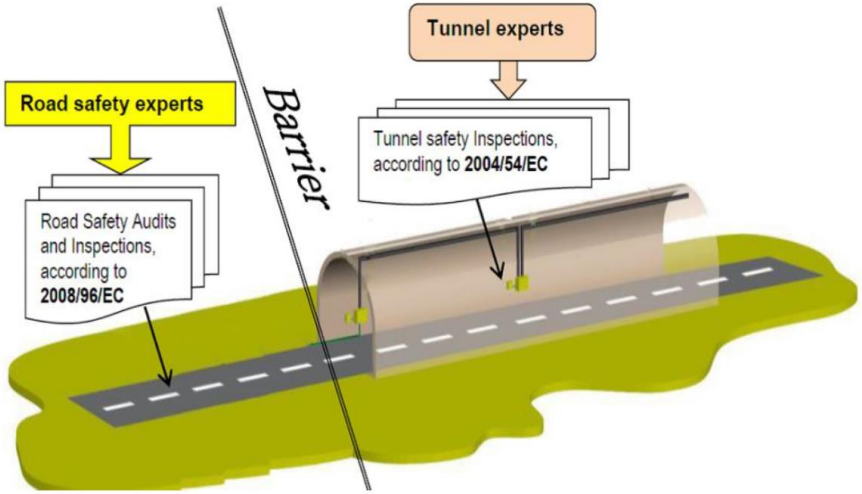


Tyne Tunnel



Open road vs tunnel safety regulations

- 2012: Belgian coach crash in Swiss tunnel killed 28, including 22 children
- Separate European directives for open road and tunnel safety regulations
- EU-funded ECOROADS research project: joint safety inspections with tunnel and open road safety experts

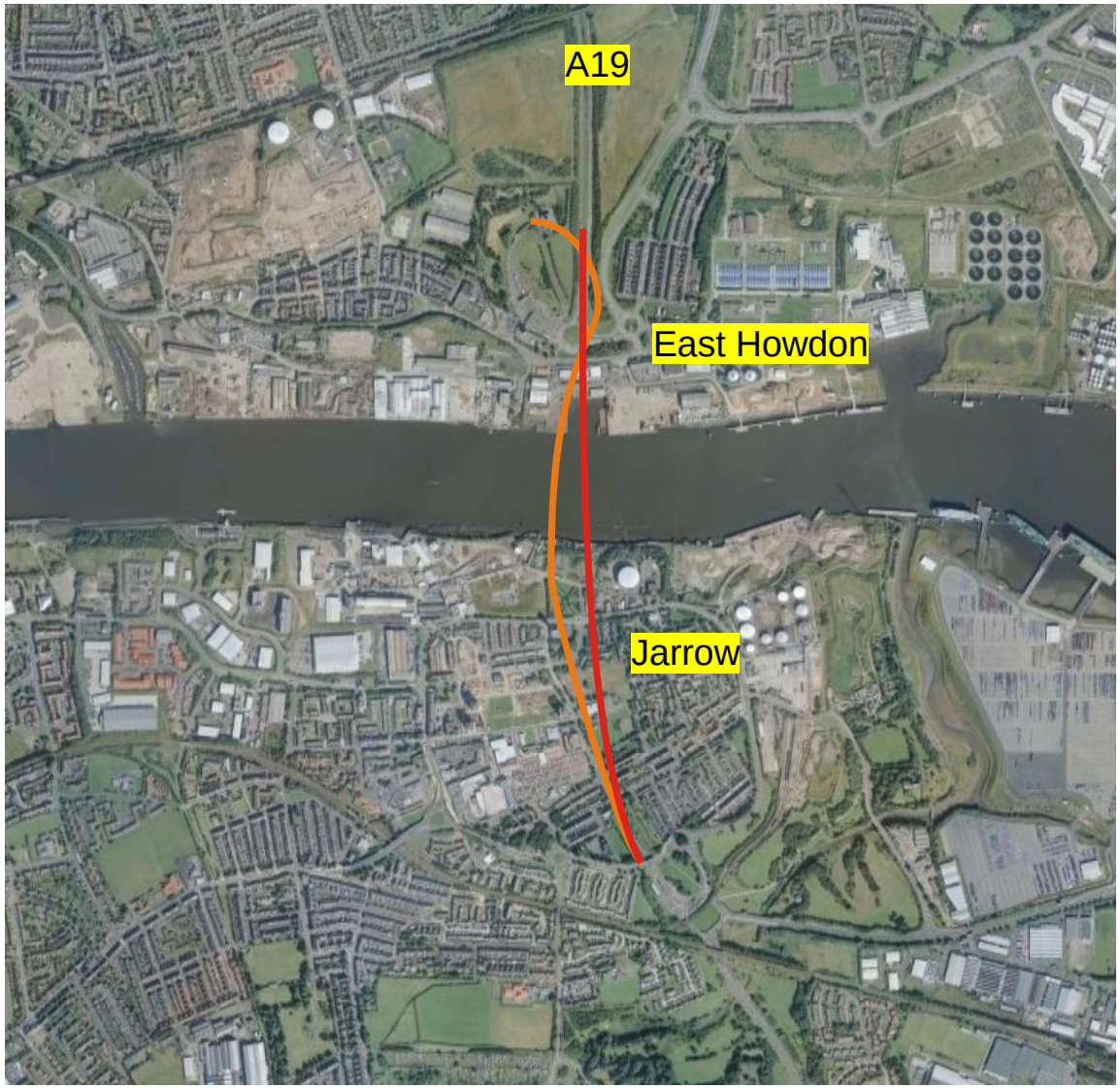


Case Study – New Tyne Crossing

The Brief

- Original tunnel was single bore, bidirectional
- New southbound tunnel constructed and opened in 2011
- Risk assessment and a cost-benefit analysis regarding the a fire suppression system in NTC
- Make a clear recommendation – yes or no

New Tyne Crossing



Operational features

Excellent safety regime at Tyne Tunnel to be continued and enhanced:

- Escorting of permitted dangerous goods vehicle through the tunnel
- Inspection of heavy goods vehicles prior to entry into the tunnel
- Tunnel control room manned 24 hours a day, with CCTV and Automatic Incident Detection monitors
- Rapid response vehicles with on-board fire-fighting facilities
- Tunnel closure barriers, to prevent entry into the tunnel in an emergency

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Structural Fire Safety Features

- A separate evacuation passageway in both tunnels, with double leaf doors at approximately 100m intervals
- Tunnel linings to resist two hours fire according to the enhanced hydrocarbon curve

Fire protection

- Duplicated power supplies
- Smoke detection via digital image processing
- Public access emergency panels at 50 metre intervals
- Locked electrical distribution point panels and Fire Service emergency panels at 50m intervals, including hydrants and gate valves
- Combustible gas detection equipment system and a foam blanket suppression in the mid-river sump, together with associated alarms.
- Comprehensive CCTV coverage of the tunnels and approach roads

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Smoke Control

- Longitudinal ventilation system via jet fans in both tunnel bores, controlled by an environmental control system and smoke panels
- Pressurised evacuation passageways

Communications

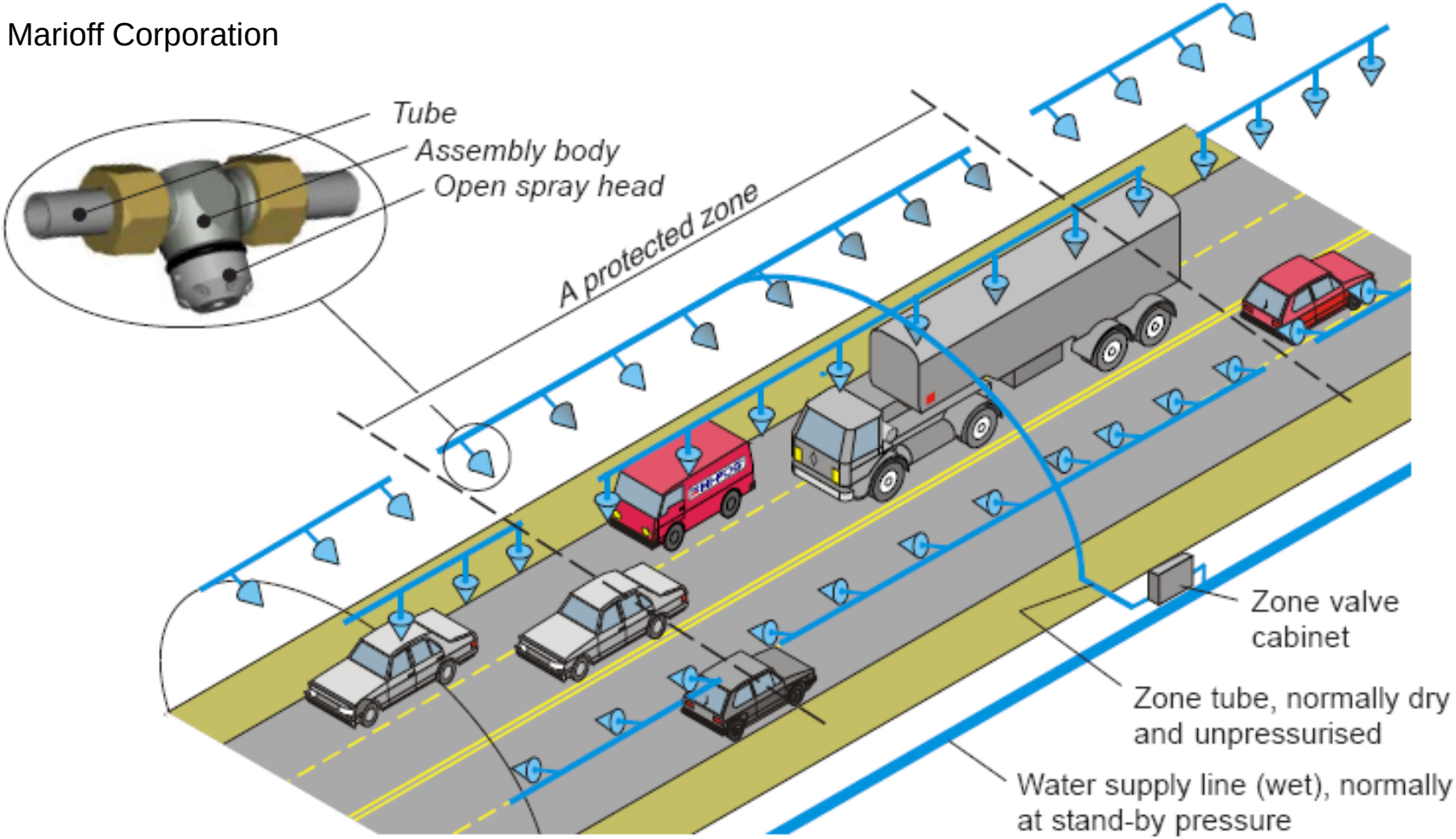
- Public use emergency telephones
- Emergency radio network with mobile phone support
- Radio Re-Broadcast and Interrupt Facilities
- A Public Address system with speakers in both the traffic spaces and the evacuation passageway

Evacuation Aids

- Provision for 10% of the minimum night time lighting to be supported by UPS equipment, for safe evacuation of the tunnel
- Internally illuminated “running man” signs above each passageway door
- Variable message board signs on the walls and inside the passageway
- ‘Switch on radio’ signs
- Wall mounted direction signs to nearside emergency exits

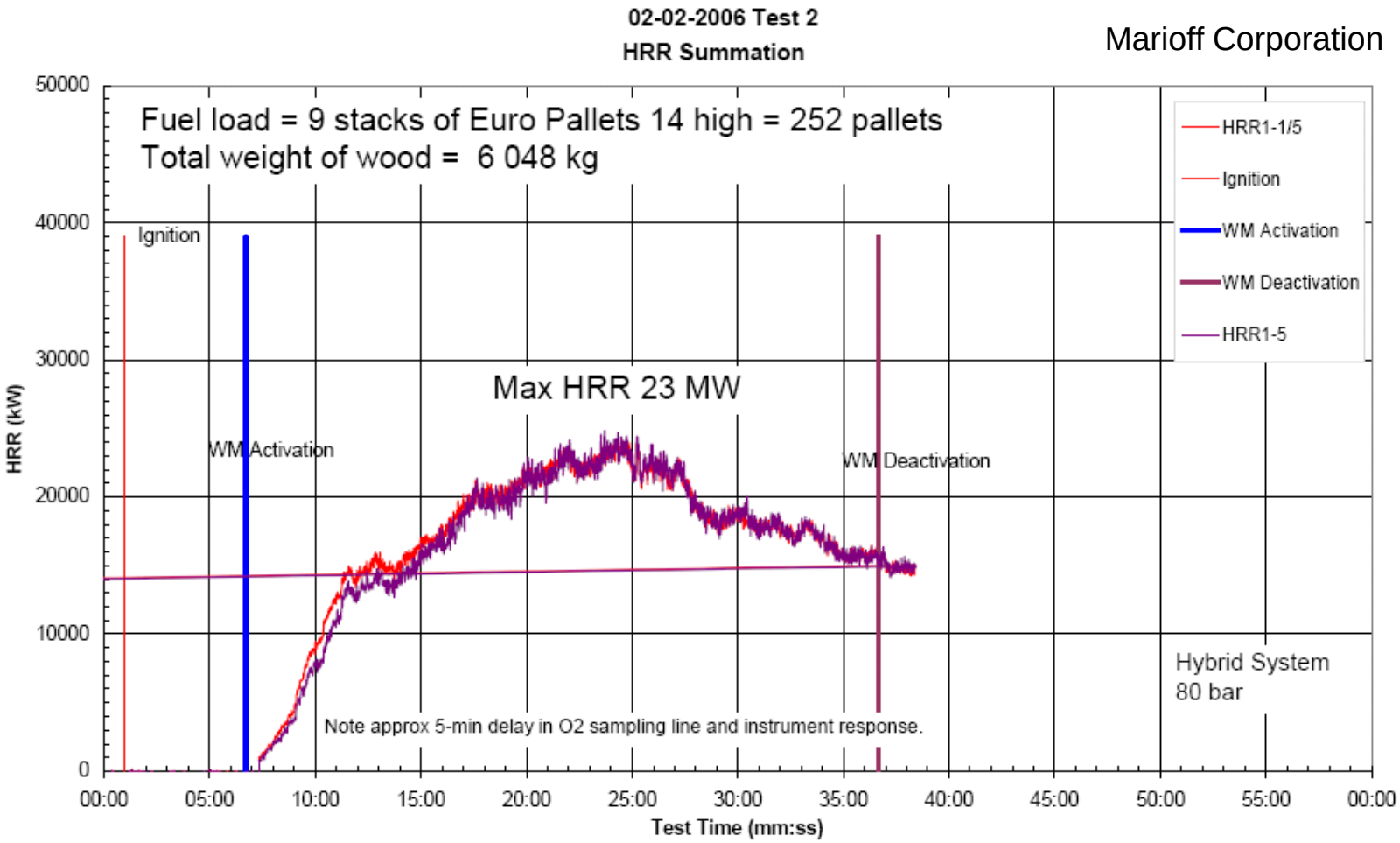
Fire Suppression System (Generic)

Marioff Corporation



Typical Fire Suppression Test Results

Marioff Corporation



Expected HRR without fire suppression = 75 MW

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Effectiveness of Fire Suppression

- For minor fires – no effect assumed
- For severe fires – 50% reduction in in fires progressing from minor to severe (for damage & delay), 25% corresponding reduction for injuries
- For very severe and catastrophic fires - 66% reduction in fires progressing from minor to severe (for damage & delay), 33% corresponding reduction for injuries

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Stakeholders' Involvement

Questionnaires sent to, and meetings held with:

- Tyne & Wear Passenger Transport Authority (now North East Combined Authority)
- Tyne Tunnels
- Bouygues Travaux Publics
- High-Point Rendel
- Highways Agency
- Tyne & Wear Fire & Rescue Service

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Cost-Benefit Assessment

- Benefit to Cost Ratio = Relevant Benefits / Relevant Costs

  over the selected assessment period

- Need to account for the time value of money, via discount rates (HM Treasury's Green Book)

- Inflation assumptions are as per the Department for Transport's COBA Manual

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Benefits and Costs

Possible benefits:

- Reduction in cost of injuries and emergency services attendance
- Reduction in traffic delays
- Reduction in cost of tunnel damage

Costs:

- Capital costs of fire suppression system
- Cost of refurbishment and maintenance for the fire suppression system

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NTC Project Phases

Year	Project Phase	Traffic flow management	Is fire suppression system an option in the operating tunnel?
2007 to 2011	1	Bi-directional	No
2011 to 2012	2	Bi-directional	Yes
After 2012	3 &4	Uni-directional	Yes

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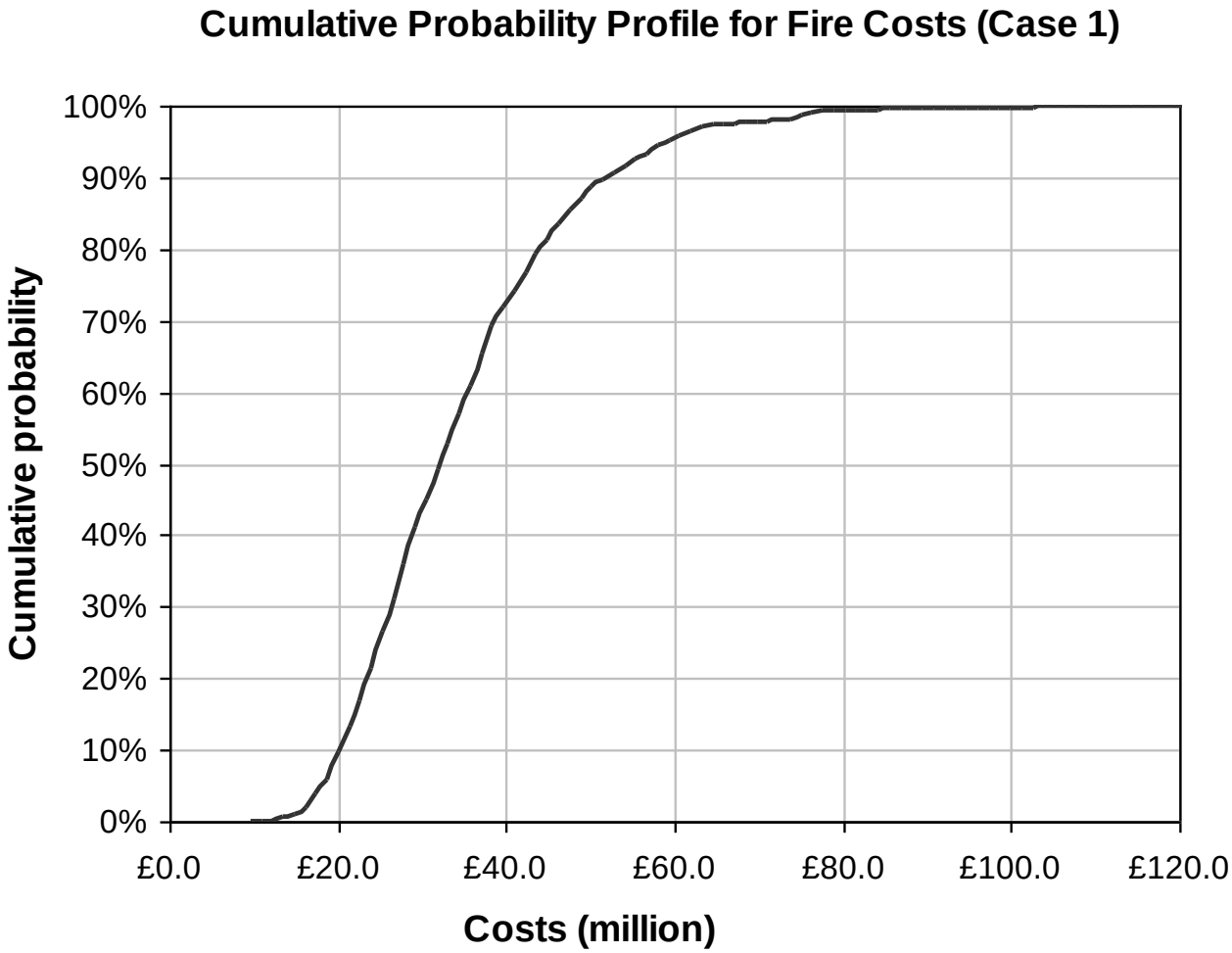
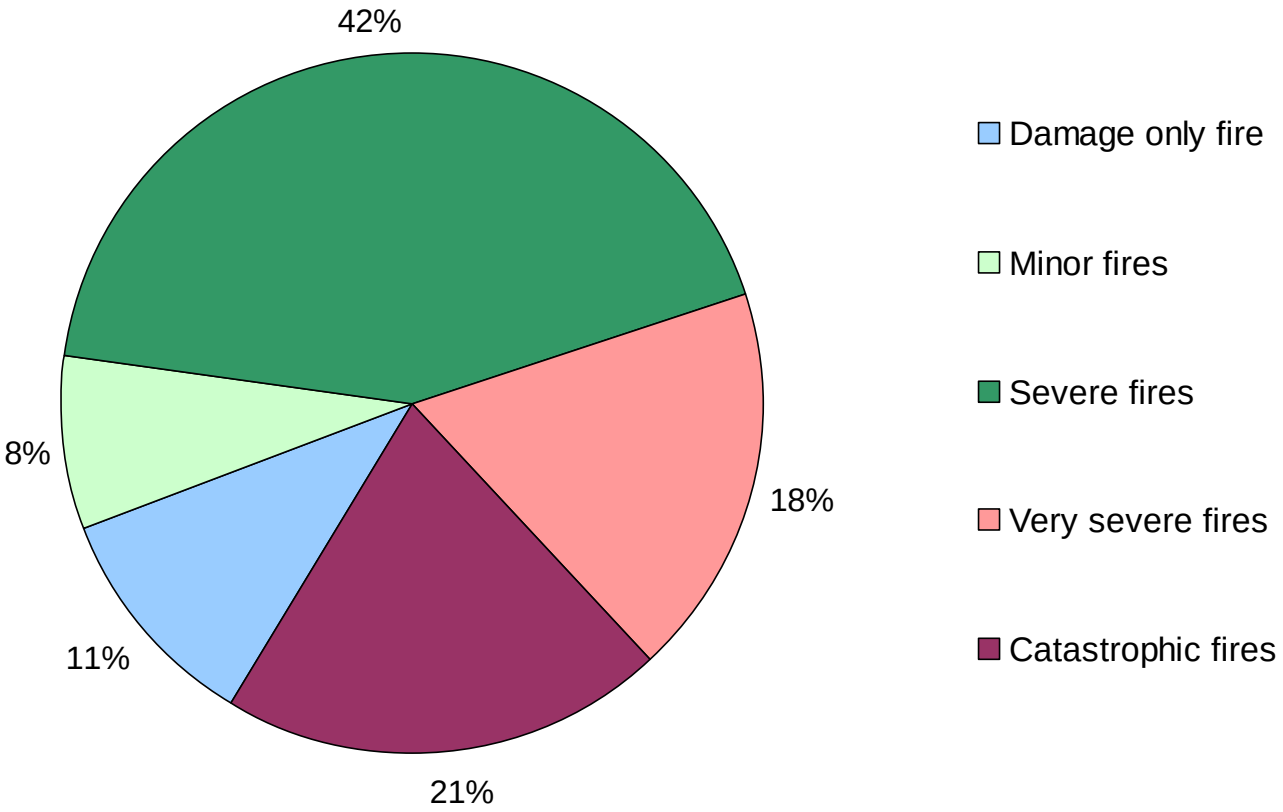
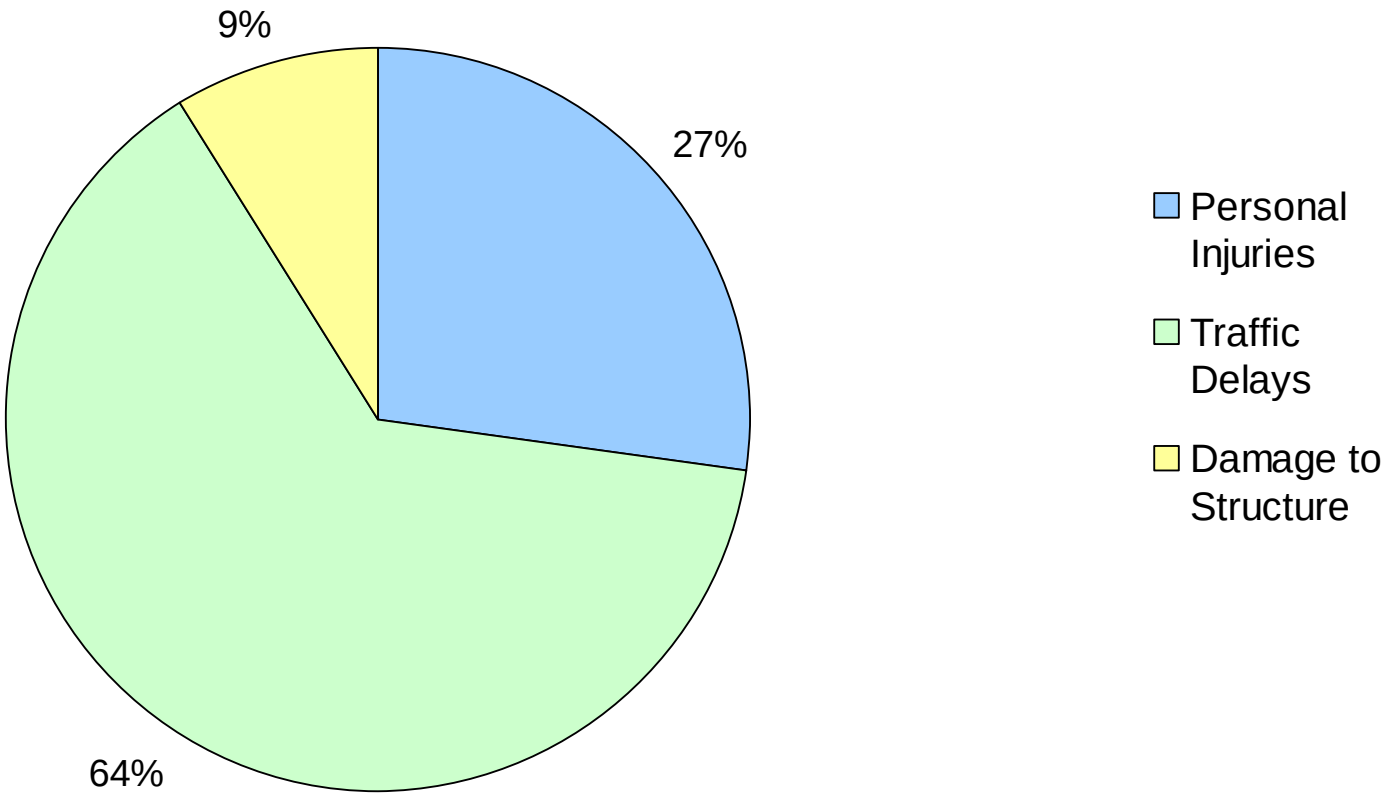
Fire Costs


Cumulative Probability Profile for Fire Costs (Case 1)
Cumulative probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
£0.0
£20.0
£40.0
£60.0
£80.0
£100.0
£120.0
Costs (million)

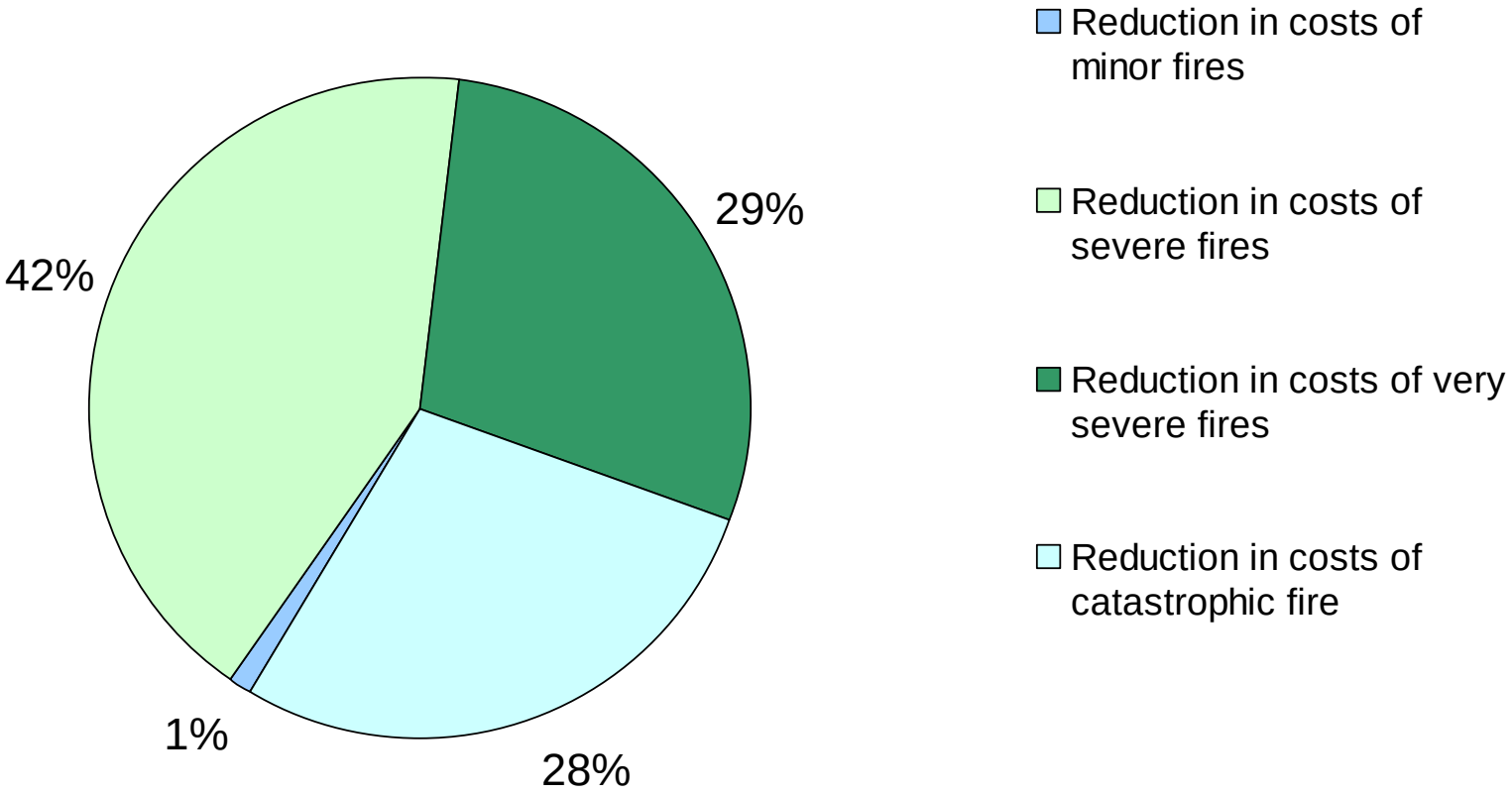
Breakdown of Fire Costs



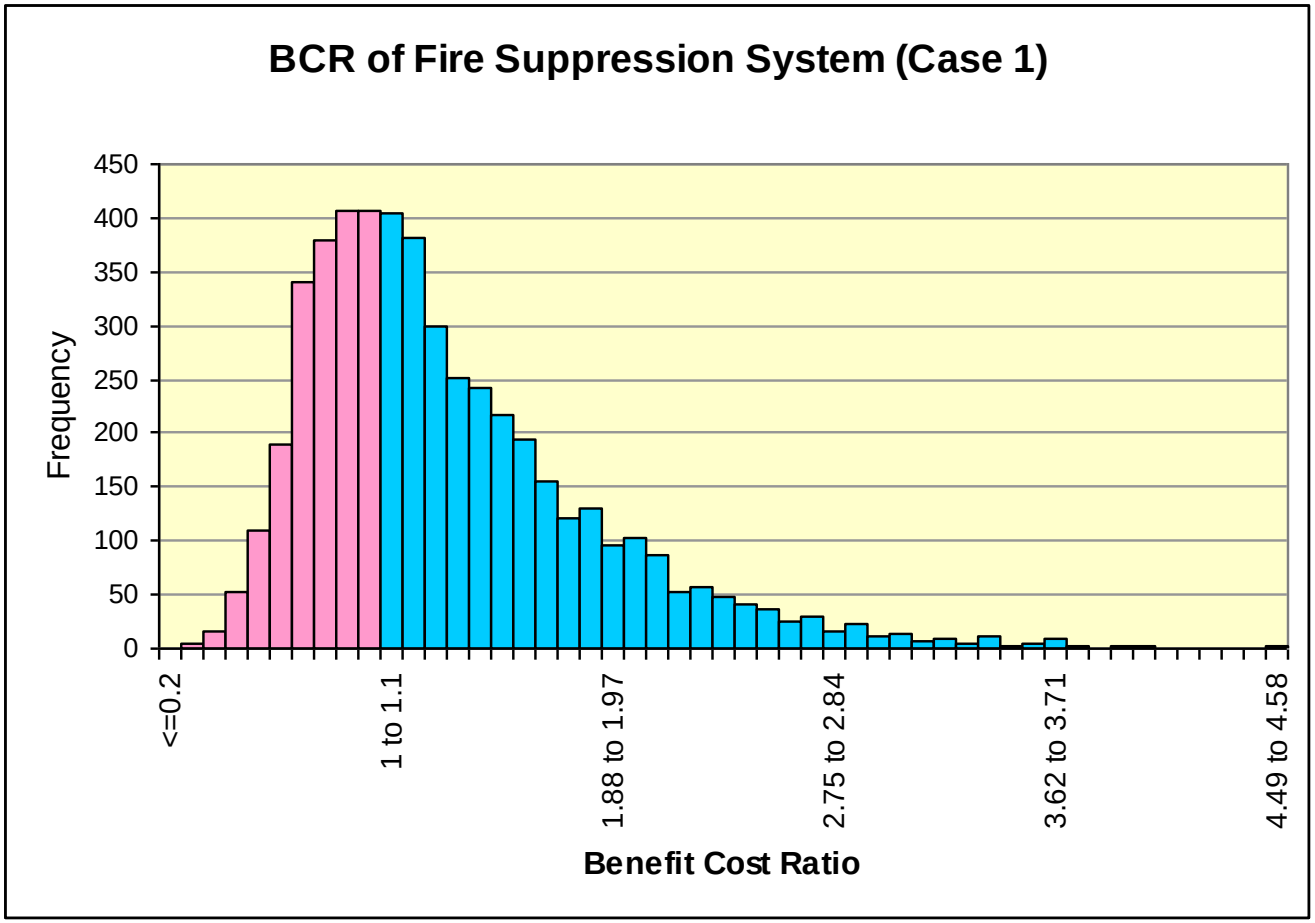
Cost Sources



Benefit Sources



Benefit to Cost Ratio



Average BCR = 1.27

Recommendation

- Installation of fixed fire suppression system recommended
- Recommendation was approved by Tunnel Design and Safety Consultation Group and TWPTA (now NECA), and installation undertaken
- Tyne Tunnel was the first road tunnel in the UK to have a fire suppression system installed

Legal Test (Common Law)

Edwards v National Coal Board [1949]:

"… a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them"

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Benefit / Cost Ratio

- Safety benefit / cost > 0.1 ?
- Can the safety benefit be reasonably and accurately determined?

Conclusions

- Large road tunnel fires at the turn of the century triggered a comprehensive review of safety approaches
- This was coded in norms and regulations to improve safety levels
- Drawbacks
  - Inconsistent approaches
  - Cost, complexity
  - Equipment aging
  - Effect on innovation

– Much more work required to improve safety at an acceptable level of cost

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Summary

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Any Questions?